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NOISE CONTROL FOR QUALITY OF LIFE

Vibration level difference measurements on a timber frame mock-up. Project AH+, part 3.

De Geetere Lieven[1], Ingelaere Bart[2], and Rychtarikova Monika[3]

[1,2,3] Belgian Building Research Institute

Lombardstraat /Rue du Lombard 42, 1000 Brussels, Belgium

ABSTRACT

CEN/TC 126/WG 2 is currently revising the EN 12354 series on prediction models for sound transmission in buildings based on the performance of elements. One major goal of this revision is the extension of the current models towards lightweight building constructions. In a first step, new expressions are being proposed to predict the flanking sound transmission due to airborne excitation. Measurements of the normalized direction-averaged vibration level difference $D_{v,ij,n}$ in a 3-room real-size timber frame mock-up have been performed in order to get input data for these new expressions. For cases where bidirectional measurements are not possible, a new expression is proposed to estimate the direction-averaged vibration level difference based on a unidirectional vibration level difference measurement.

Keywords: Vibration, Measurement

1. INTRODUCTION

CEN/TC 126/WG 2 is currently revising the EN 12354 series on prediction models for sound transmission in buildings based on the performance of elements. One major goal of this revision is the extension of the current models towards lightweight building constructions. In a first step, new expressions are being proposed to predict the flanking sound transmission due to airborne excitation. The goal of this paper is to provide input data for these prediction models by measuring the newly introduced normalized direction-averaged vibration level difference $\overline{D_{v,ij,n,R}}$ in a 3-room real-size timber frame mock-up with basic walls and floors and to compare these with the vibration reduction index K_{ij} of corresponding heavy homogeneous constructions.

2. BACKGROUND IN EN 12354-1

According to prEN 12354-1:2013 [1], the flanking sound reduction index in heavy homogeneous constructions can be estimated by

1 lieven.de.geetere@bbri.be
2 bart.ingelaere@bbri.be
3 monika.rychtarikova@bbri.be

$$R_{ij,situ} = \frac{R_{i,R,situ} + R_{j,R,situ}}{2} + K_{ij} - 10\lg\frac{l_{ij,situ}}{\sqrt{a_{i,situ}a_{j,situ}}} + 10\lg\frac{S_{S,situ}}{\sqrt{S_{i,situ}S_{j,situ}}}, \quad (1)$$

in which the in-situ damping characteristics of the connecting building elements are taken into account by their equivalent absorption lengths $a_{i,situ}$. The subscript R denotes that only resonant sound transmission is considered.

In lightweight timber frame constructions however, the damping in the connected elements is largely independent of their surrounding structure. Similarly, the flanking transmission can be approximately characterised by

$$R_{ij,situ} = \frac{R_{i,R,situ} + R_{j,R,situ}}{2} + \overline{D_{v,ij,n,R}} - 10\lg\frac{l_{ij,situ}l_0}{\sqrt{S_{i,situ}S_{j,situ}}} + 10\lg\frac{S_{S,situ}}{\sqrt{S_{i,situ}S_{j,situ}}}, \quad (2)$$

which can be further simplified to

$$R_{ij,situ} = \frac{R_{i,R,situ} + R_{j,R,situ}}{2} + \overline{D_{v,ij,n,R}} + 10\lg\frac{S_{S,situ}}{l_{ij,situ}l_0}. \quad (3)$$

The normalized direction-averaged vibration level difference $\overline{D_{v,ij,n,R}}$ is a property of the junction which takes into account vibration level reduction over the connected elements. It can be measured in laboratory according to ISO 10848-1 [2] by

$$\overline{D_{v,ij,n,R}} = \overline{D_{v,ij,R}} + 10\lg\frac{l_{ij}l_0}{\sqrt{S_iS_j}}. \quad (4)$$

If the measurement areas are not too small the result will be independent of the actual area.

In this study, $\overline{D_{v,ij,n,R}}$ is measured in a real-size timber frame mock-up for several flanking paths to and compared to K_{ij} predictions in corresponding heavy homogeneous constructions.

3. MOCK-UP

The mock-up is constructed using single-stud walls and simple joist floors (see Figures 1 & 2).

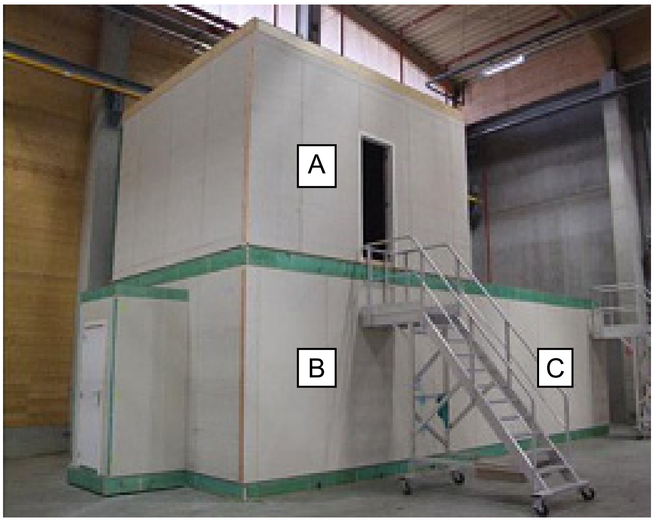

Figure 1 – Mock-up

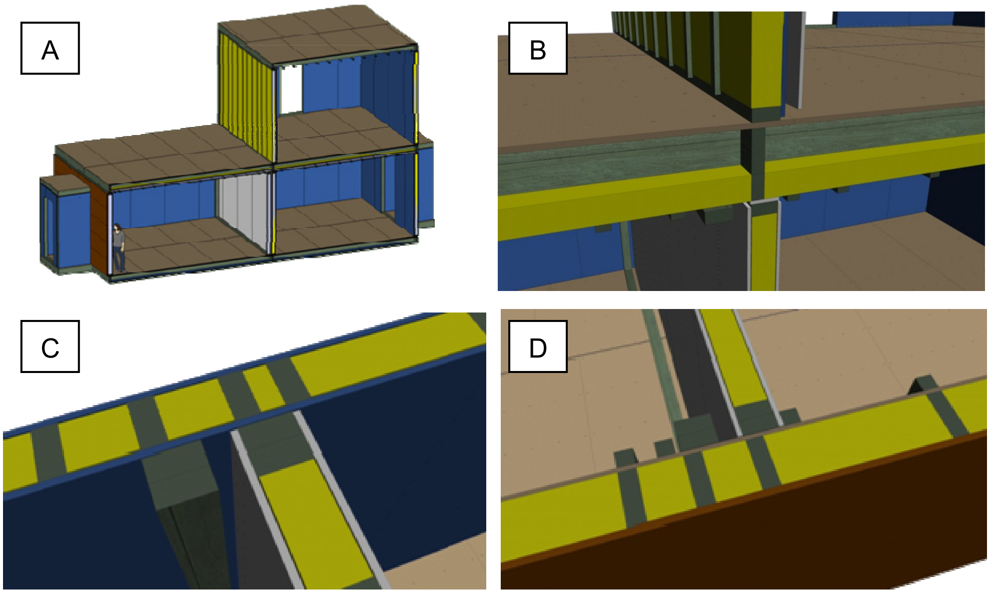

Figure 2 – A: Vertical cut - B: connection between floor and partition wall. - C: connection between partition wall and 'interior' walls. - D: connection between partition wall and 'exterior' walls.

Some walls, including the partition wall are designed as interior walls inside a dwelling. Other walls are designed as exterior walls, but without façade cladding. The 'interior' walls and the partition wall have wooden studs with a section of 95x45 mm, 40 cm o.c., filled with 95 mm mineral wool and on both sides a screwed 12.5 mm fibre reinforced gypsum board. The 'exterior walls' have wooden studs with a section of 140x45 mm, 40 cm o.c., filled with 140 mm mineral wool, on the inside a screwed 12 mm particle board and on the outside a screwed 18 mm softboard. The floors have continuous joists with a section of 240x45 mm, 40 cm o.c., crossing the partition wall, an 18 mm particle board subfloor on top and a 12.5 mm gypsum board screwed on wood furring strips 40 cm o.c. below. The space between the joists is partly filled with 90 mm mineral wool.

4. MEASUREMENT METHOD

Velocity level difference measurements are made between wall and floor elements according to equation (4) using a hammer or a wooden stick as impact source. 12 accelerometer positions on each element are used and all requirements in ISO 10848-1 [2] are respected. However, in order to avoid having to shield certain building elements for the airborne sound generated by the impacts, it was decided to excite the elements from the outside of the cells under consideration. Further, due to the strongly decaying vibration field, it was decided to spread the impact positions over the whole element surface during each measurement, so a better signal to noise ratio could be obtained. The accelerometers were attached to the elements using glued thin mounting studs.

In cases where the element in the source room is orthogonal to the element in the receiving room, it was not possible to measure the direction-averaged junction velocity level difference because the transducers not attached to the separating element were too much excited by airborne vibrations generated by the impacts on the separating element, as illustrated in Figure 3. In these cases, the normalized direction-averaged vibration level difference cannot be estimated by equation (4) but may be approximated by a normalized unidirectional vibration level difference. For heavy homogeneous construction, this normalized unidirectional vibration level difference can be measured by [3]

$$K_{ij} = -10\lg \gamma_{ij} = D_{v,ij,R} + 10\lg\left(\frac{m_i c_{B,i}}{m_j c_{B,j}}\right) + 10\lg\left(\frac{l_{ij}}{a_j}\right), \tag{5}$$

in which m_i and $c_{B,i}$ are the surface mass [kg/m²] and the bending wave speed [m/s] for building element i respectively. For lightweight timber frame constructions, this expression may – in the same way as for equation (2) – be translated into

$$D_{v,ij,n,R} = D_{v,ij,R} + 10\lg\left(\frac{m_i}{m_j}\sqrt{\frac{f_{c,j}}{f_{c,i}}}\right) + 10\lg\left(\frac{l_{ij} l_0}{S_j}\right). \tag{6}$$

In the cases described above, equation (6) is used to estimate the direction-averaged junction velocity level difference.

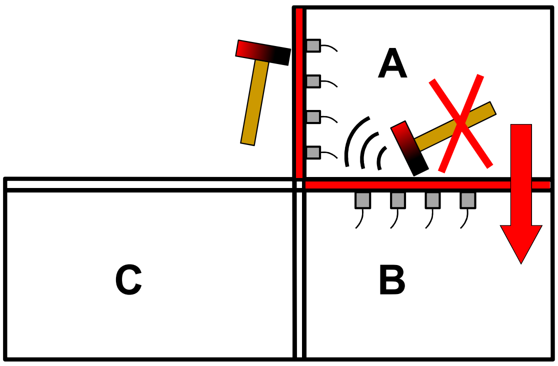

Figure 3 – The airborne sound generated by the impacts in cell A excite the transducers in A, making it impossible to measure this flanking path from B to A.

5. MEASUREMENT RESULTS

Measurements of the direction-averaged junction velocity level difference have been made across the cross junction and the 'exterior' T-junctions between cells A & B and between cells C and B. As can be seen from Figure 4, the obtained single-number values (as an average of the third-octave band values from 200 to 1250 Hz) are much higher than what would be predicted for massive homogeneous constructions with corresponding surface mass ratios following EN 12354-1 ($\overline{K_{ij}}$ varying from 6 to 11 dB). The highest value of 30 dB corresponds to the Ff path in the cross junction along the partition wall and can be explained by the fact that the partition wall is interrupted twice by the floor. Because the subfloor and joists of the floor are continuous across the cross junction and hardly coupled with the partition wall, this also explains the lowest value of 7 dB for the Ff path along the floor.

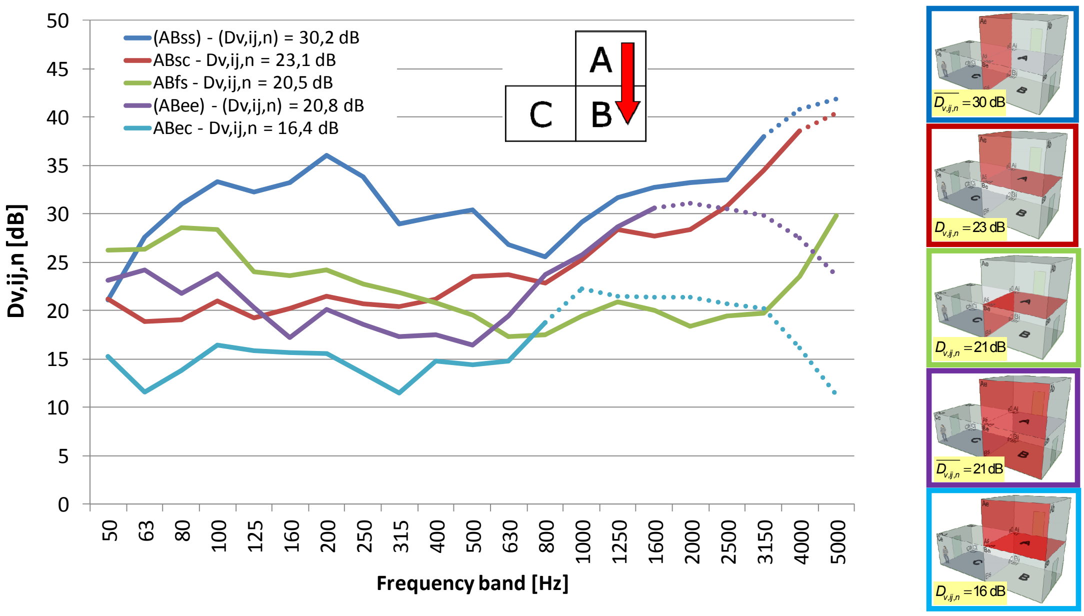

Figure 4a – Measured normalized vibration level difference across the cross junction and the 'exterior' T-junction between cells A and B. Dotted lines mean minimal values due to background noise problems (SNR < 6 dB at receiving side).

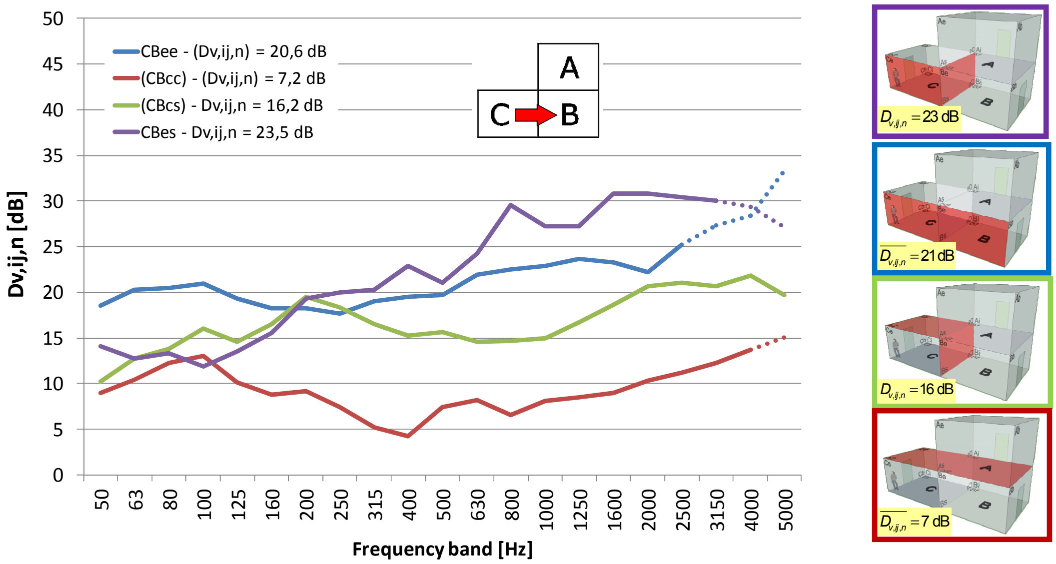

Figure 4b – Measured normalized vibration level difference across the cross junction and the 'exterior' T-junction between cells C and B. Dotted lines mean minimal values due to background noise problems (SNR < 6 dB at receiving side).

The relatively weak coupling of the elements in the junctions (connections with screws only) compared to massive homogeneous constructions partly explain the globally high values in Figure 4. The spatially decaying vibration field in the elements also contributes substantially to the normalised vibration level difference. This effect is studied in detail in a companion paper [4]. The decay rate (in dB/m) has been measured in the mock-up for different walls (parallel to the studs) and the floor (parallel and normal to the joists) by structurally exciting building elements connected to the elements studied and measuring the vibration level in several points on a line normal to the junction between the excited element and the measured element. Since all vibration waves need to cross this junction, it is assumed that geometrical dispersion is eliminated from the measured decay. Results are shown in Figure 5. Also shown is a rough linear approximation that leads to the following guideline for estimating decay rates in simple timber stud walls or floors (partly) filled with mineral wool: on average 0/2/4 dB/m at 50/500/5000 Hz resp. in the direction parallel to joists or studs and 0/7/14 dB/m at 50/500/5000 Hz resp. in the direction perpendicular to the joists.

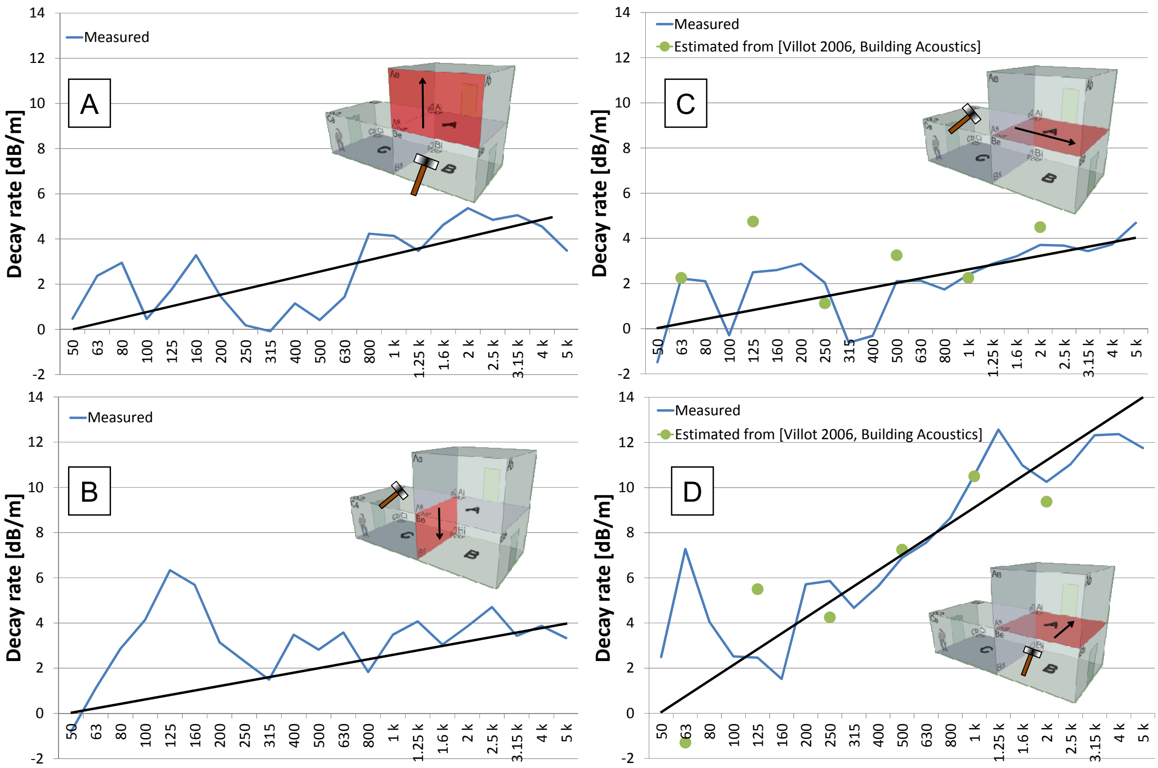

Figure 5 – Measured (blue curves) and approximated (black lines) vibration level decay rate over several timber framed elements in the mock-up. Estimated values on comparable constructions according to [5] – A: 12 mm particle board parallel to studs – B: 12.5 mm fiber reinforced gypsum board parallel to studs – C: 18 mm particle board parallel to joists – D: 18 mm particle board normal to joists

6. CONCLUSIONS

The normalized vibration level differences in lightweight timber frame constructions are usually much larger than the vibration reduction indices of massive homogeneous constructions with corresponding surface masses, except for flanking paths along building elements that are continuous over the junction with supporting joists or studs normal to the junction. This is explained by the weak coupling in the junctions and the spatially decaying vibration field in the elements.

ACKNOWLEDGEMENTS

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